

A Modular Pressurized Exosuit Concept Using Controlled Gas Pockets for Extravehicular Activities

Eng. Leonardo Gabriel Téllez Saucedo
Independent Researcher
Email: leonardo616@gmail.com

Abstract—Traditional space suits rely on fully pressurized envelopes to provide life support in the vacuum of space. However, these systems impose severe mobility constraints and require complex pressure regulation mechanisms. This paper introduces a conceptual design for a modular exosuit that achieves physiological pressure through an array of dynamically controlled inflatable cells, positioned beneath protective armor plates. The design decouples the pressure generation from the suits structural flexibility, offering a potentially lighter and more agile alternative for extravehicular activities (EVA). This concept aims to stimulate further research toward hybrid mechanical-pressurized suits capable of ensuring astronaut safety while significantly improving comfort and mobility.

Index Terms—Space suit, mechanical counterpressure, gas regulation, exosuit, EVA design, astronautics.

I. INTRODUCTION

Modern extravehicular mobility units (EMUs) rely on gas-pressurized chambers that maintain internal suit pressure around 4.3 psi to sustain human life in vacuum. Despite their proven safety, these systems introduce significant stiffness, reduce dexterity, and impose metabolic costs on astronauts [1]. Several mechanical counterpressure (MCP) suit concepts, including the MIT BioSuit [2], attempt to overcome these issues by using elastic materials to apply direct pressure to the body. While promising, purely elastic MCP designs face challenges in maintaining uniform pressure distribution, donning complexity, and material fatigue.

This paper presents an alternative concept: a hybrid modular exosuit that uses micro-controlled inflatable gas pockets between semi-rigid armor segments and the astronauts under-layer garment. The system aims to offer adaptive pressure control without relying solely on elasticity, providing both protection and flexibility.

II. CONCEPT OVERVIEW

The proposed design consists of three principal layers:

- **Base Layer:** A semi-elastic undergarment that ensures close body fit, allowing localized pressure transmission.
- **Inflatable Layer:** A network of micro gas pockets that can be inflated with nitrogen or other inert gas through electronically controlled valves, enabling precise pressure adjustments.
- **Protective Layer:** Rigid but lightweight shields made of advanced composites such as graphene-reinforced polymers or carbon-fiber laminates, providing impact, micrometeoroid, and radiation protection.

The suit incorporates an embedded microprocessor that continuously monitors pressure sensors across the body, adjusting gas flow to maintain optimal counterpressure. A distributed valve system enables zone-specific control, allowing variable stiffness in different parts of the body.

III. SYSTEM DESIGN

A. Pressure Regulation Mechanism

Each inflatable cell contains a miniature pressure transducer and microvalve. The system is closed-loop regulated, responding dynamically to body posture and external forces. Nitrogen is used as the working gas due to its inert nature and compatibility with spacecraft systems.

B. Control Electronics

The regulation system is managed by a microcontroller interfaced with pressure sensors and actuated valves. Data is processed in real time to maintain equilibrium across the body, ensuring a target pressure equivalent to that of traditional suits (approximately 30 kPa).

C. Mobility and Comfort

Articulated joints such as shoulders, elbows, knees, and hips employ hybrid regions of elastic Kevlar-spandex fabric instead of rigid plates. This provides both flexibility and localized tension when surrounding pockets are pressurized.

IV. MATERIALS AND SAFETY CONSIDERATIONS

The system prioritizes non-flammable materials. The gas circuit is isolated from the life-support oxygen line to prevent combustion risks. Armor panels made of graphene composites offer a favorable strength-to-weight ratio while providing enhanced protection against micrometeoroids and thermal radiation.

V. DISCUSSION

This concept merges the advantages of mechanical counterpressure suits and gas-pressurized systems. While not yet tested experimentally, the modular pressure cell approach could simplify maintenance, enhance reliability, and allow adaptive pressure profiles based on mission phase or physiological needs.

Potential research directions include:

- Experimental validation of gas pocket pressure distribution.

- Development of smart fabrics integrating microfluidic channels.
- Evaluation of thermal and structural performance in vacuum environments.

VI. CONCLUSION

The proposed modular exosuit represents an early-stage conceptual framework for next-generation EVA systems. By replacing continuous pressurization with controlled, distributed gas pockets, astronauts could gain enhanced agility, safety, and comfort. This paper aims to encourage further interdisciplinary research combining aerospace engineering, material science, and bioengineering.

ACKNOWLEDGMENT

The author acknowledges the assistance of ChatGPT (OpenAI, 2025) for conceptual structuring and English language editing.

REFERENCES

- [1] NASA, "Extravehicular Mobility Unit (EMU) Overview," NASA Technical Report, 2019.
- [2] D. Newman et al., "The MIT BioSuit System for Space Exploration," *Acta Astronautica*, vol. 59, no. 1, pp. 113–123, 2006.